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(54) POWER GENERATING APPARATUS WITH WATER TURBINE WITH BI-SYMMETRIC AIRFOIL

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Description

FIELD OF NVENTION

[0001] The present invention relates to a power generation apparatus as defined in the preamble of claim 1
[0002] Such an apparatus is known eg from WO 03/029645.

BACKGROUND TO INVENTION

[0003] Underwater power generators, e.g. for generating electrical power, and associated turbine units are known.
[0004] WO 03/029645 A1 (also by the present Applicant) discloses a power generator, such as an electrical power generator, comprising at least one underwater turbine unit including a housing having a liquid flow channel therethrough and at least one turbine means mounted in the flow channel for rotation in response to liquid flow through the channel. The turbine unit also comprises a pump means operatively coupled to the turbine means. The turbine unit provides a turbine unit part releasably mountable in the turbine unit, the part including at least one of the at least one turbine means and the pump means. In the disclosed embodiments the turbine unit part also comprises at least part of the flow channel.
[0005] CH-A-316900 describes a power generation apparatus with an underwater turbine having blades which are of a bi-symmetrical shape.
[0006] Known tidal or current electrical power generators seek to address a need for increasing energy requirements in an environmentally friendly way. However, known generators suffer from a number of problems, e.g. relatively low efficiency of conversion of tidal and/or current flow to electrical energy.
[0007] So-called "symmetrical" aerofoils are known, and are employed for the stabilising surfaces of aircraft, such as the fin and tailplane, and also for wings of highly aerobatic aircraft which require the "lift" force to be high in both positive and negative directions. These aerofoils have zero "camber" or, in other words, a straight mean line which is clothed with a streamline form symmetrical about the mean line. Such a streamline form is asymmetrical fore and aft, with a blunt leading edge and a sharp trailing edge. This form has also been used for ships hulls. Conventionally, the leading edge or "entry" has been easier to design than the rearward curves or "run" of a ship's hull. This reflects the generally accelerating flow with falling pressure at the front, whereas the flow must decelerate towards the trailing edge and the rising pressure there tends to force a "separation" of the flow from the surface. The resulting chaotic wake gives very high drag, and where aircraft wings are concerned, a collapse of lift.
[0008] A wide variety of aerofoil forms have been developed and investigated throughout the last century. Systematic design philosophies were developed by NACA in particular, using families of streamline shapes to clad camber lines of varying curvature. Even when the camber is zero and the camber line just a straight line, the empirical streamline shapes vary in the position of maximum thickness and the relative size of the leading edge.
[0009] It is an object of at least one embodiment of at least one aspect of the present invention to obviate or at least mitigate one or more problems in the prior art.
[0010] It is a further object of one or more embodiments of at least one aspect of the present invention to provide an underwater turbine unit which, in use, is driven by tidal and/or current flow, and which can preferably operate in ebb and/or flood tides without a need for movement or realignment into a tidal flow direction.
[0011] It is a yet further object of at least one embodiment of at least one aspect of the present invention to provide a power generator apparatus or farm which is substantially or wholly underwater, thereby minimising environment impact.

SUMMARY OF INVENTION

[0012] According to a first aspect of the present invention there is provided a power generation apparatus according to claim 1. The aerofoil of the blade is symmetrical about a mid-chord line thereof.
[0013] Herein, by mid-chord line is meant a line extending heightwise or breadthwise from substantially half way along a chord of the aerofoil.
[0014] The aerofoil is symmetrical about a chord thereof.
[0015] Such an aerofoil may therefore be said to be bi-symmetrical.
[0016] The aerofoil comprises first and second leading edges.
[0017] Preferably each leading edge is part circular in shape.
[0018] Preferably the chord of the aerofoil comprises a straight line. In other words a camber of the aerofoil is zero, and a camber line comprises a straight line.
[0019] The mid-chord line is substantially perpendicular to the chord.
[0020] Preferably a height of the aerofoil is greatest at or around the mid-chord line, reducing towards either end.
[0021] Preferably a ratio of mid-chord line height or thickness to chord length is around 5% to 25%, most preferably 12% to 20%, and advantageously substantially 15%.
[0022] Most preferably a position of maximum height or thickness of the aerofoil is substantially at the mid-chord line, i.e. 50% along the chord.
[0023] An advantageous implementation of the present invention provides a bi-symmetrical aerofoil with zero camber and maximum height or thickness at mid-chord.
[0024] Most preferably the aerofoil shape comprises a

NACA 67, particularly a NACA 67_1-015, leading edge shape reflected about a mid-chord line.

[0025] According to a second aspect, of the present invention there is provided a method of generating power according to claim 38, said method comprising at least an apparatus according to the first aspect of the present invention.

[0026] The blade, comprises a plurality of aerofoils (or design sections, e.g. longitudinally spaced sections) according to the first aspect of the present invention, for example, in the range of 3 to 9, and preferably 5.

[0027] Preferably a taper ratio, i.e. tip chord to hub chord ratio, may be in the range 0.3 to 0.8, and preferably around 0.5.

[0028] Preferably an aspect ratio, i.e. mean chord to blade height ratio, may be in the range 3 to 10, and preferably around 6.

[0029] The hub setting angle of the aerofoils are in the range 30° to 60° from an axial direction, and preferably around 45° or 48°.

[0030] The tip setting angle is in the range 70° to 85° from an axial direction, and preferably around 79°.

[0031] Preferably a blade chord length at mid height may be in the range 0.3m to 3.0m, and preferably around 1.0m.

[0032] The turbine may comprise a plurality of blades, e.g. in the range 2 to 9 blades, preferably 3 to 7 blades, in advantageous implementations 5 or 7 blades.

[0033] Preferably a ratio of hub diameter to tip diameter may be in the range of 0.1 to 0.5, and preferably around 0.2.

[0034] Preferably a tip diameter may be in the range 5m to 30m, and preferably around 15m to 20m.

[0035] The turbine may be adapted to rotate, in use, at a rate of 10 rpm to 50 rpm, and preferably around 25 rpm.

[0036] Preferably the turbine unit includes a housing having a fluid or liquid flow channel therethrough and the at least one turbine according to the present invention is mounted in the flow channel for rotation in response to liquid flow through the flow channel.

[0037] The flow channel may comprise a venturi, e.g. a convergent-divergent venturi, tapering from openings at either end of the flow channel towards an inner part of the flow channel. This arrangement may, in use, provide a zone of acceleration for fluid flow through the flow channel.

[0038] The housing may be substantially symmetrical about a mid-point location thereof, and the at least one turbine may be located substantially thereat.

[0039] The liquid may be provided from a body of water within which the turbine unit is submerged.

[0040] The turbine housing may comprise an inner housing sleeve, and optionally an outer housing sleeve, which inner sleeve defines the flow channel.

[0041] The housing may be secured to an underwater surface by a mounting structure and may be substantially aligned with a direction of tidal (tidal stream) or current flow.

[0042] An angle between an axial direction of the housing and a direction of tidal or current flow may be around 0° to 45°, and preferably between 0 to 22°, and beneficially around 0°.

[0043] The turbine unit may provide a part releasably mountable in the turbine unit. The part may include at least one of the turbine and the pump means.

[0044] The turbine unit part may include at least a part of the housing, e.g. at least part of the flow channel, which may comprise at least part of the inner housing sleeve.

[0045] Preferably the turbine unit may be driven, i.e. the turbine may be caused to rotate, in use, in response to fluid (e.g. tidal and/or current) flow in either direction through the flow channel. In other words the turbine unit may work in both ebb and flood tides. The turbine may rotate in a first direction of rotation in a first direction of tidal flow, and the turbine may rotate in a second, opposite, direction of rotation in a second, opposite direction of tidal flow.

[0046] Preferably an inlet and/or outlet (exit) diameter of the flow channel or duct may be in the range 7m to 40m, and preferably around 20m.

[0047] Preferably a length of the flow channel or duct may be in the range 7m to 50m, and preferably around 28m.

[0048] Most preferably the power generation apparatus comprises an electrical power generator.

[0049] Preferably, the power generation apparatus may further comprise:

a pump means operatively coupled to the at least one turbine;

a generator means driven by the turbine, and optionally located separately from the at least one turbine unit; and

a fluid supply means coupling the pump means to the generator means for supplying fluid from the pump means to the generator means for generating power.

[0050] The fluid may comprise the liquid.

[0051] The power generation apparatus may be adapted to produce electrical power as alternating current/voltage (AC) or direct current/voltage (DC).

[0052] Preferably the at least one turbine unit is located on, near, or above a sea bed, ocean floor, river bed or the like.

[0053] Preferably the fluid flow may comprise tidal flow, e.g. of ebb and/or flood tides, tidal stream flow, or current flow.

[0054] Preferably the at least one turbine rotates in one direction in response to fluid flow in one direction and the at least one turbine rotates in another or counter direction in response to fluid flow in another direction.

[0055] The one direction and the another direction of fluid may be at least partly opposite in direction, and may be substantially opposed in direction, e.g. the one direc-

tion may be a direction of an ebb tide flow and the another direction may be a direction of a flood tide flow.

BRIEF DESCRIPTION OF DRAWINGS

[0056] Embodiments of the present invention will now be described by way of example only, and with reference to the accompanying drawings, which are:

Figure 1 a cross-sectional side view of an aerofoil according to an embodiment of the present invention;

Figure 2 a perspective view from one side and one end of a blade comprising an aerofoil according to Figure 1;

Figure 3 a perspective view of a turbine comprising a plurality of blades according to Figure 2;

Figure 4 a perspective view of an underwater turbine unit comprising a turbine according to Figure 3;

Figure 5 a schematic view of an underwater power generation apparatus according to a first embodiment of the present invention comprising a plurality of turbine units according to Figure 4;

Figure 6 a graphical representation of velocity distributions at various incidence angles for the aerofoil of Figure 1;

Figure 7 a graphical representation of predicted behaviour for the aerofoil of Figure 1;

Figure 8 a schematic view of an underwater power generation apparatus according to a second embodiment of the present invention; and

Figure 9 a schematic view of the underwater power generation apparatus of Figure 8 during a maintenance procedure.

DETAILED DESCRIPTION OF DRAWINGS

[0057] Referring initially to Figure 1 there is shown an aerofoil, generally designated 5, according to an embodiment of the present invention. The aerofoil 5 is symmetrical about a mid-chord line A thereof. Herein by mid-chord line A is meant a line extending height wise (or width wise) from substantially half way along a chord B of the aerofoil 5. In this embodiment, the aerofoil 5 is also symmetrical about the chord B. The aerofoil 5 may therefore be said to be "bisymmetrical".

[0058] The aerofoil 5 comprises first and second leading edges 10, 15, each leading edge 10, 15 being part circular in shape.

[0059] The chord B of the aerofoil 5 comprises a straight line. In other words a camber of the aerofoil 5 is zero, and a camber line comprises a straight line. The mid-chord line A can be seen to be perpendicular to the chord B. Further a height of the aerofoil 5 is greatest at or around the mid-chord line A, reducing towards either end, that is, towards each leading edge 10,15. A ratio of mid- chord line height or thickness to chord length is typically around 5% to 25%, more typically between 12% and 20%, and in this embodiment around 15%. Further, the position of maximum height or thickness of the aerofoil 5 is substantially at the mid-chord line A, i.e. around 50% of the way along the chord B. The present embodiment of the aerofoil 5 therefore provides a bisymmetrical aerofoil 5 with zero camber and maximum height or thickness at mid- chord.

[0060] The shape of the aerofoil 5 in a preferred implementation of this embodiment comprises a NACA 67 series profile, particularly a NACA 67_1-015, leading edge shape reflected about a mid-chord line.

[0061] Referring now to Figure 2, there is illustrated a blade 20 comprising at least one aerofoil 5. The blade 20 comprises a plurality of aerofoils (or longitudinal spaced design sections) 5a to 5e, for example, in the range of 3 to 9 design sections, and preferably as shown in Figure 2, 5 design sections.

[0062] A taper ratio, i.e. tip chord to hub chord ratio can be in the range of 0.2 to 0.8, and in this embodiment around 0.5. An aspect ratio, i.e. mean chord to blade height ratio, can be in the range of 3 to 10, and in this embodiment around 5. A hub setting or stagger angle can be in the range of 30° to 60° from axial direction, and in this embodiment around 45° or 48°. A tip setting or stagger angle can be in the range of 70° to 85° from an axial direction, and in this embodiment around 79°. It will therefore be appreciated that between hub and tip the blade 20 is typically twisted. A blade chord length at mid-height can be in the range of 0.3 metres to 3 metres, and in this embodiment around 1 metre.

[0063] Referring now to Figure 3 there is illustrated a turbine, generally designated 25, comprising at least one blade 20. In this embodiment the turbine 25 comprises a plurality of blades 20a to 20e, for example, in the range 2 to 9 blades and typically in the range 3 to 7 blades, and in this advantageous implementation, 5 blades - although in an alternative advantageous implementation, 7 blades may be provided. The turbine 25 comprises a hub structure 30 upon which is mounted a rotating hub 35 from which the blades 20a to 20e outwardly and radially extend.

[0064] A ratio of hub diameter to tip diameter is in the range 0.1 to 0.5, and in this embodiment around 0.2. A tip diameter is in the range 5 metres to 30 metres, and in this embodiment around 15 metres. Further the turbine 25 is adapted to rotate in use at a rate of around 10 rpm to 50 rpm, and in this embodiment at around 25 rpm.

[0065] Referring now to Figure 4, there is illustrated a

turbine unit, and particularly an underwater turbine unit or apparatus, generally designated 30, comprising a turbine 25. The turbine unit 30 includes a housing or duct 35 having a liquid or fluid flow channel 40 therethrough and at least one turbine 25 mounted in the flow channel 40 for rotation in response to liquid/fluid (water) flow through the flow channel 40. The flow channel 40 defines a flow restriction which comprises a venturi comprising a convergent-divergent venturi, tapering from openings 45,50 at either end of the flow channel 40 towards an inner part 55 of the flow channel 40. The housing 35 is substantially symmetrical about a mid-point location 55 and the turbine 25 is located substantially at the mid-point location 55 within the flow channel 40. The turbine unit 30 also includes a support structure for supporting the turbine unit 30 upon a seabed, ocean floor, riverbed, or the like, which support structure is not shown in Figure 4. The liquid for driving the turbine 25 is provided from a body of water within which the turbine unit 30 is submerged - e.g. sea water.

[0066] As shown in Figure 4 the housing or duct 35 comprises a single sleeve. In such implementation the housing or duct 35 has a narrowed or reduced waist on an outer surface thereof between ends thereof, and in this case, substantially mid-way between the ends thereof. However, in a modified implementation the turbine housing 35 can comprise an outer housing sleeve and an inner housing sleeve which inner sleeve defines the flow channel 40.

[0067] In use the housing 35 can be secured to an underwater surface by a support or mounting structure (not shown) and substantially aligned to a direction of predicted tidal or current flow. The angle between the actual direction of the housing 35 and the direction of tidal or current flow can be between 0° to 45°, and in this embodiment typically around 0°.

[0068] An inlet and/or outlet diameter of the flow channel 40 can be in the range 7 metres to 40 metres, and in this embodiment typically around 20 metres. The length of the flow channel 40 or duct can be in the range 7 metres to 50 metres, and typically in this embodiment around 28 metres. As can be seen from Figure 4, the turbine unit 30 also includes support struts 41 for supporting the turbine 25 within the duct 35. Further, the stationary hub 30 comprises a nose cone 42 and tail cone 43.

[0069] Referring now to Figure 5, there is illustrated a power generation apparatus, generally designated 60, comprising a plurality of turbine units 30 operatively linked or connected by electrical cable 65. Each of the turbine units 30 includes a supporting structure 70 for locating the respective turbine unit 30 on seabed 75. The power generation apparatus 60 comprises in the embodiment an electrical power generator. The power generation apparatus 60 comprises within each turbine unit 30: a pump means operatively coupled to the at least one turbine 25; a generator means (not shown) driven by the turbine 25 and optionally located separately from the at least one turbine unit 30; and a fluid supply means coupling the pump to the generator means for supplying fluid from the pump means to the generator means for generating power. The fluid optionally and advantageously comprises the liquid within which the turbine units 30 are submerged.

[0070] The power generation apparatus 60 can be adapted to produce electrical power as alternating current (AC) or direct current (DC).

[0071] In use the generation apparatus 60 is employed in a method of generating power. The method comprises the steps of:

providing the power generation apparatus 60;
locating each turbine unit 30 of the power generation apparatus 60 underwater; and
causing the at least one turbine 25 of the at least one turbine unit 30 to rotate in response to fluid flow in at least one direction, and preferably in both tidal flow directions.

[0072] The at least one turbine unit 30 is located on a seabed, ocean floor, river bed or the like as can be seen from Figure 5. The fluid flow comprises tidal flow or stream, e.g. ebb and/or flow tides or alternatively current flow. The at least one turbine 25 rotates in one direction in response to fluid flow in one direction and in another or counter direction in response to fluid flow in another direction. The one direction and another direction of fluid flow can be at least partly opposite in direction and may be substantially opposite in direction, e.g. one direction may be a direction of an ebb tide flow and the other direction may be the direction of a flood tide flow.

[0073] The requirement to operate equally well in both directions forces a compromise in aerofoil design - in effect a choice between two leading edges back to back or two trailing edges back to back. Although a thin trailing edge is considered important for low drag, a thin leading edge will not tend to tolerate variations in incidence angle and it is important that aerofoils should not stall at incidence angles of at least 5° degrees and preferably up to 10°. The aerofoil 5 therefore has a rounded leading edge and the drag will be minimised by limiting the maximum thickness.

[0074] The maximum thickness is located at the mid-point of the aerofoil 5 at 50% chord, which makes it a very unusual aerofoil 5 for low speed applications. The leading edge geometry is not arbitrary. Calculations using an Eppler aerofoil design and analysis program showed that a simple stretched ellipse would likely not be satisfactory, even when the leading edges were enlarged. Eppler R, "Aerofoil Design and Data" Springer, 1991.

[0075] A standard aerofoil leading edge can be selected, but the choice is restricted because almost all previously published aerofoils have their maximum thickness ahead of mid-chord. The NACA 67-series aerofoils do, however, meet this requirement, using the basic thickness form designated NACA 67_1-015. Such have a max-

imum thickness of 15% which offers a low overall drag together with reasonable spar depth. The aerofoil 5 is one of those designed to achieve a large region of laminar flow, which will not be relevant at the likely operating Reynolds numbers, but the smoothly developing flow which this design process achieves nevertheless ensures good boundary layer development together with tolerance of flow at incidence. As the bi-symmetrical aerofoil 5 has no camber, all the lift must be produced by operating at non-zero incidence.

[0076] The disclosed embodiment of this novel aerofoil 5 is therefore based on the front half of NACA 67_1-015, reflected about the 50% chord line. In the course of the analysis, it was found necessary to add extra definition points on the leading and trailing edge circles. The coordinates of the aerofoils shape are specified in Table 1 below:

Table 1: Coordinates of the bi-symmetrical Aerofoil 5:

x %c	y_u %c	y_l %c
0.000	0.000	0.000
0.100	0.559	-0.559
0.300	0.937	-0.937
0.500	1.167	-1.167
0.750	1.394	-1.394
1.250	1.764	-1.764
2.500	2.395	-2.395
5.000	3.245	-3.245
7.500	3.900	-3.900
10.000	4.433	-4.433
15.000	5.283	-5.283
20.000	5.940	-5.940
25.000	6.454	-6.454
30.000	6.854	-6.854
35.000	7.155	-7.155
40.000	7.359	-7.359
45.000	7.475	-7.475
50.000	7.497	-7.497
55.000	7.475	-7.475
60.000	7.359	-7.359
65.000	7.155	-7.155
70.000	6.854	-6.854
75.000	6.454	-6.454
80.000	5.940	-5.940
85.000	5.283	-5.283
90.000	4.433	-4.433
92.500	3.900	-3.900
95.000	3.245	-3.245
97.500	2.395	-2.395
98.750	1.764	-1.764
99.250	1.394	-1.394
99.500	1.167	-1.167
99.700	0.937	-0.937
99.900	0.559	-0.559
100.000	0.000	0.000

U = upper
L = lower

[0077] The aerofoil 5 has been analysed using an Eppler program which calculates the velocity distribution and boundary layer development. At the Reynolds Number of interest, in the range 3 to 10 million, the program predicts no "bubble warnings" and no laminar or turbulent separation. The profile and its predicted velocity distributions at incidence angles from zero to 12 degrees are shown in Figure 6.

[0078] Figure 7 shows the results of the Eppler program. The drag coefficient lies below 0.010 at lift coefficients up to 0.5, which corresponds to about 4.5° incidence angle. The results for a 5 million Reynolds Number indicate a laminar flow "drag bucket" with the drag coefficient falling to 0.006 at zero incidence. This effect is stronger at even lower Reynolds Numbers.

[0079] The predicted drag coefficients translate into predicted turbine efficiencies of 85% to 90%, although this depends on assumptions made for secondary losses.

[0080] Model turbine tests have confirmed that a model ducted turbine using the aerofoil 5 achieved efficiencies of 80% to 85% in both directions, at Reynolds Numbers - based on blade chord - of round 300,000.

[0081] The 15% thick aerofoil 5 described here provides a good compromise between structural and aerodynamic efficiency, but there are advantages to choosing other thicknesses in certain circumstances. For example, the turbine blades will benefit from the increased rigidity of a 20% thickness-chord ratio at the root section and a thinner 12% thick form at the tip. There are two ways of achieving such a "family" of similar bi-symmetrical aerofoils.

[0082] First, the basic NACA 67_1-015 thickness form can be scaled to any desired thickness before reflecting the profile about its mid-chord line. The performance of the resulting profile can then be checked using aerofoil and boundary layer analysis software or CFD.

[0083] Second, a more sophisticated approach is to use the Eppler program, for example, to design a novel but conventional symmetrical aerofoil having the desired thickness, with its maximum thickness at 50% chord, and then to reflect this profile about its mid-chord. The second method is more reliable because the original NACA profile was designed in a similar fashion and its aerodynamic properties are not necessarily retained when it is simply scaled. The design software ensures a favourable velocity distribution is achieved up to a certain prescribed value of incidence angle.

[0084] Referring now to Figures 8 and 9, there is shown a power generation apparatus, generally designated 160 according to second embodiment of the present inven-

tion. The power generation apparatus 160 comprises a plurality of turbine units 130 and is similar to the power generation apparatus 60 of the first embodiment shown in Figure 5, including blades (not shown) having the form of the aerofoil 5 of Figure 1.

[0085] However, the turbine units 130 of Figures 8 and 9 differ from the turbine units 30 of the power generation apparatus 60 of Figure 5 in that the turbine units 130 provide a part 165 releasably mountable in the turbine unit 130. The part 165 includes at least one of the turbine and the pump means (not shown). Advantageously, as can be seen from Figure 9 the part 165 includes at least part of the duct 135. The part 165 is releasable from the turbine unit 130 via an openably closeable part 170. The part 165 can be retrieved to surface by a vessel 175, or the like, for maintenance or replacement purposes and may thereafter be reinstalled or replaced in the turbine unit 130.

[0086] The power generation apparatus 160 of Figures 8 and 9 therefore resembles the power generation apparatus disclosed in WO 03/029645 A1 (also by the present Applicant), but includes the novel and inventive aerofoil 5 of the present invention.

[0087] The foregoing embodiments provide ducted turbines which do not need an underwater yawing mechanism but allow the tidal flow to power the turbine in either direction. This is achieved by the novel turbine blade design which provides a relatively high efficiency when operating with flow in either direction. As the turbine blade angle to the axial direction is relatively high, the direction of rotation of the turbine will be reversed when the tidal flow direction changes.

[0088] It will also be appreciated that although in the disclosed embodiment the turbine unit has one turbine, it may be envisaged that in variants a turbine unit may have more than one turbine, e.g. in series.

Claims

1. A power generation apparatus (60) comprising at least one underwater turbine unit (30), the at least one underwater turbine unit comprising at least one turbine (25), the at least one turbine comprising at least one blade (20a-20e), **characterized in that** the at least one blade comprises a plurality of aerofoils (5a-5e) which are spaced along a length of the at least one blade and between a hub and a tip of the at least one blade, wherein each aerofoil is of a shape which is symmetrical about a mid-chord line (A) thereof and which is symmetrical about a chord line (B) thereof, and wherein each aerofoil comprises first and second leading edges (10, 15), and first and second leading edges of adjacent aerofoils are joined so as to provide respective continuous first and second leading edges of the at least one blade, and further wherein a hub setting angle of the at least one blade is in the range of 30° to 60° from an axial direction, and a tip setting angle of the at least one blade is in the range 70° to 85° from an axial direction.

2. A power generation apparatus as claimed in claim 1, wherein the at least one turbine unit includes a housing 35 having a fluid flow channel (40) therethrough, the at least one turbine being mounted in the flow channel for rotation in response to fluid flow through the flow channel.

3. A power generation apparatus as claimed in any preceding claim, wherein each leading edge is part circular in shape.

4. A power generation apparatus as claimed in any preceding claim, wherein for each aerofoil a ratio of mid-chord line height or thickness to chord line length is 5% to 25%.

5. A power generation apparatus as claimed in any preceding claim, wherein for each aerofoil a ratio of mid-chord line height or thickness to chord line length is 12% to 20%.

6. A power generation apparatus as claimed in any preceding claim, wherein for each aerofoil a ratio of mid-chord line height or thickness to chord length is 15%.

7. A power generation apparatus as claimed in any preceding claim, wherein each aerofoil shape comprises a NACA 67 leading edge shape reflected about the mid-chord line.

8. A power generation apparatus as claimed in any preceding claim, wherein each aerofoil shape comprises a NACA 67_1-015 leading edge shape reflected about the mid-chord line.

9. A power generation apparatus as claimed in any preceding claim, wherein the at least one blade comprises 3 to 9 aerofoils

10. A power generation apparatus as claimed in any preceding claim, wherein the at least one blade comprises five aerofoils.

11. A power generation apparatus as claimed in any preceding claim, wherein a taper ratio of the at least one blade is in the range 0.3 to 0.8.

12. A power generation apparatus as claimed in any preceding claim, wherein a taper ratio is 0.5.

13. A power generation apparatus as claimed in any preceding claim, wherein an aspect ratio of the at least one blade is in the range 3 to 10.

14. A power generation apparatus as claimed in any pre-

ceding claim, wherein an aspect ratio of the at least one blade is around 6.

15. A power generation apparatus as claimed in any preceding claim, wherein a hub setting angle of the at least one blade is 45° or 48°.

16. A power generation apparatus as claimed in any preceding claim, wherein a tip setting angle of the at least one blade is 79°.

17. A power generation apparatus as claimed in any preceding claim, wherein a chord length of the at least one blade at mid-height is in the range 0.3m to 3.0m.

18. A power generation apparatus as claimed in any preceding claim, wherein a chord length of the at least one blade is 1.0m.

19. A power generation apparatus as claimed in any preceding claim, wherein the at least one blade comprises a plurality of blades.

20. A power generation apparatus as claimed in claim 19, wherein the plurality of blades comprises 2 to 9 blades.

21. A power generation apparatus as claimed in either of claims 19 or 20, wherein the plurality of blades comprises 3 to 7 blades.

22. A power generation apparatus as claimed in any of claims 19 to 21, wherein the plurality of blades comprises 5 or 7 blades.

23. A power generation apparatus as claimed in any of claims 19 to 22, wherein a ratio of hub diameter to tip diameter of the at least one blade is in the range of 0.1 to 0.5.

24. A power generation apparatus as claimed in any of claims 19 to 23, wherein a ratio of hub diameter to tip diameter of the at least one blade is 0.2.

25. A power generation apparatus as claimed in any of claims 19 to 24, wherein a tip diameter is in the range 5m to 30m.

26. A power generation apparatus as claimed in any of claims 19 to 25, wherein a tip diameter is 15m to 20m.

27. A power generation apparatus as claimed in any of claims 19 to 26, wherein the turbine is adapted to rotate, in use, at a rate of 10 to 50 rpm.

28. A power generation apparatus as claimed in any of claims 19 to 27, wherein the turbine is adapted to rotate, in use, at a rate of 25 rpm.

29. A power generation apparatus as claimed in claim 2 or any of claims 3 to 28 when dependent upon claim 2, wherein the flow channel comprises a venturi comprising a convergent-divergent venturi, tapering from openings at either end of the flow channel towards an inner part of the flow channel.

30. A power generation apparatus as claimed in claim 2, wherein the housing is substantially symmetrical about a mid-point location thereof, and the/at least one of the at least one turbine(s) is located substantially thereat.

31. A power generation apparatus as claimed in either of claims 29 to 30, wherein the turbine housing comprises an outer housing sleeve and an inner housing sleeve, which inner sleeve defines the flow channel.

32. A power generation apparatus as claimed in any of claims 29 to 31, wherein the turbine unit provides a part releasably mountable in the turbine unit.

33. A power generation apparatus as claimed in any of claims 1 to 32, wherein the turbine unit is driven, in use, in response to fluid flow in either direction through the flow channel.

34. A power generation apparatus as claimed in claim 2 or any of claims 3 to 33 when dependent upon claim 2, where an inlet and/or outlet diameter of the flow channel or duct is selected from in the range 7m to 40m, or is 20m.

35. A power generation apparatus as claimed in claim 2 or any of claims 3 to 34 when dependent upon claim 2, wherein a length of the flow channel or duct is in the range 7m to 50m.

36. A power generation apparatus as claimed in any preceding claim, wherein the power generation apparatus comprises an electrical power generator.

37. A power generation apparatus as claimed in claim 36, wherein the power generation apparatus is adapted to produce electrical power as alternating current/voltage (AC) or direct current/voltage (DC).

38. A method of generating power comprising the steps of:

providing a power generation apparatus (60) according to any of claims 1 to 37;
locating the at least one turbine unit (30) of the power generation apparatus underwater;
causing the at least one turbine (25) of the at least one turbine unit to rotate in response to fluid flow in at least one direction.

39. A method of generating power as claimed in claim 38, wherein the at least one turbine unit is located on, near, or above one of: a sea-bed, ocean floor, or riverbed.

40. A method of generating power as claimed in either of claims 38 or 39, wherein the fluid flow comprises tidal flow or current flow.

41. A method of generating power as claimed in any of claims 38 to 40, wherein the at least one turbine rotates in one direction in response to fluid flow in one direction and the at least one turbine rotates in another or counter-direction in response to fluid flow in another direction.

42. A power generation apparatus as claimed in claim 38, wherein the housing is secured to an underwater surface by a mounting structure and is optionally substantially aligned with a direction of tidal or current flow.

43. A power generation apparatus as claimed in claim 42, wherein an angle between an axial direction of the housing and a direction of tidal or current flow is 0° to 45°.

44. A power generation apparatus as claimed in claim 42, wherein an angle between an axial direction of the housing and a direction of tidal or current flow is 0°.

Patentansprüche

1. Energieerzeugungsvorrichtung (60), die wenigstens eine Unterwasser-Turbineneinheit (30) umfasst, wobei die wenigstens eine Unterwasser-Turbineneinheit wenigstens eine Turbine (25) umfasst, wobei die wenigstens eine Turbine wenigstens eine Schaufel (20a-20e) umfasst, **dadurch gekennzeichnet, dass** die wenigstens eine Schaufel eine Vielzahl von Flügeln (5a-5e) umfasst, die mit Zwischenraum längs einer Länge der wenigstens einen Schaufel und zwischen einer Nabe und einer Spitze der wenigstens einen Schaufel angeordnet sind, wobei jeder Flügel eine Form hat, die symmetrisch um eine Sehnenmittellinie (A) desselben ist und die symmetrisch um eine Sehnenlinie (B) desselben ist, und wobei jeder Flügel eine erste und eine zweite Vorderkante (10, 15) umfasst und die erste und die zweite Vorderkante von benachbarten Flügeln so miteinander verbunden sind, dass sie jeweilige kontinuierliche erste und zweite Vorderkanten der wenigstens einen Schaufel bereitstellen, und wobei ferner ein Nabenanstellwinkel der wenigstens einen Schaufel in dem Bereich von 30° bis 60° von einer axialen Richtung liegt und ein Spitzenanstellwinkel der wenigstens einen Schaufel in dem Bereich von 70° bis 85° von einer axialen Richtung liegt.

2. Energieerzeugungsvorrichtung nach Anspruch 1, wobei die wenigstens eine Turbineneinheit ein Gehäuse (35) einschließt, das einen Fluid-Durchflusskanal (40) durch dasselbe hat, wobei die wenigstens eine Turbine in dem Durchflusskanal angebracht ist, für eine Drehung als Reaktion auf einen Fluid-Durchfluss durch den Durchflusskanal.

3. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei jede Vorderkante von teilkreisförmiger Gestalt ist.

4. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei für jeden Flügel ein Verhältnis der Sehnenmittellinienhöhe oder -dicke zu der Sehnenlinienlänge 5% bis 25% beträgt.

5. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei für jeden Flügel ein Verhältnis der Sehnenmittellinienhöhe oder -dicke zu der Sehnenlinienlänge 12% bis 20% beträgt.

6. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei für jeden Flügel ein Verhältnis der Sehnenmittellinienhöhe oder -dicke zu der Sehnenlänge 15% beträgt.

7. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei jede Flügelform eine NACA-67-Vorderkantenform, die um die Sehnenmittellinie gespiegelt ist, umfasst.

8. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei jede Flügelform eine NACA-67_1-015-Vorderkantenform, die um die Sehnennittellinie gespiegelt ist, umfasst.

9. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei die wenigstens eine Schaufel 3 bis 9 Flügel umfasst.

10. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei die wenigstens eine Schaufel fünf Flügel umfasst.

11. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei ein Zuspitzungsverhältnis der wenigstens einen Schaufel in dem Bereich von 0,3 bis 0,8 liegt.

12. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei ein Zuspitzungsverhältnis 0,5 beträgt.

13. Energieerzeugungsvorrichtung nach einem der vor-

hergehenden Ansprüche, wobei ein Zuschärfungsverhältnis der wenigstens einen Schaufel in dem Bereich von 3 bis 10 liegt.

14. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei ein Zuschärfungsverhältnis der wenigstens einen Schaufel rund 6 beträgt.

15. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei ein Nabenanstellwinkel der wenigstens einen Schaufel 45° oder 48° beträgt.

16. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei ein Spitzenanstellwinkel der wenigstens einen Schaufel 79° beträgt.

17. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei eine Sehnenlänge der wenigstens einen Schaufel bei der Mittelhöhe in dem Bereich von 0,3 m bis 3,0 m liegt.

18. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei eine Sehnenlänge der wenigstens einen Schaufel 1,0 m beträgt.

19. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei die wenigstens eine Schaufel eine Vielzahl von Schaufeln umfasst.

20. Energieerzeugungsvorrichtung nach Anspruch 19, wobei die Vielzahl von Schaufeln 2 bis 9 Schaufeln umfasst.

21. Energieerzeugungsvorrichtung nach einem der Ansprüche 19 oder 20, wobei die Vielzahl von Schaufeln 3 bis 7 Schaufeln umfasst.

22. Energieerzeugungsvorrichtung nach einem der Ansprüche 19 bis 21, wobei die Vielzahl von Schaufeln 5 oder 7 Schaufeln umfasst.

23. Energieerzeugungsvorrichtung nach einem der Ansprüche 19 bis 22, wobei ein Verhältnis des Nabendurchmessers zu dem Spitzendurchmesser der wenigstens einen Schaufel in dem Bereich von 0,1 bis 0,5 liegt.

24. Energieerzeugungsvorrichtung nach einem der Ansprüche 19 bis 23, wobei ein Verhältnis des Nabendurchmessers zu dem Spitzendurchmesser der wenigstens einen Schaufel 0,2 beträgt.

25. Energieerzeugungsvorrichtung nach einem der Ansprüche 19 bis 24, wobei ein Spitzendurchmesser in dem Bereich von 5 m bis 30 m liegt.

26. Energieerzeugungsvorrichtung nach einem der Ansprüche 19 bis 25, wobei ein Spitzendurchmesser 15 m bis 20 m beträgt.

27. Energieerzeugungsvorrichtung nach einem der Ansprüche 19 bis 26, wobei die Turbine dafür eingerichtet ist, sich bei Anwendung mit einer Geschwindigkeit von 10 bis 50 U/min zu drehen.

28. Energieerzeugungsvorrichtung nach einem der Ansprüche 19 bis 27, wobei die Turbine dafür eingerichtet ist, sich bei Anwendung mit einer Geschwindigkeit von 25 U/min zu drehen.

29. Energieerzeugungsvorrichtung nach Anspruch 2 oder einem der Ansprüche 3 bis 28, soweit abhängig von Anspruch 2, wobei der Durchflusskanal ein Venturi-Rohr umfasst, das ein konvergent-divergentes Venturi-Rohr umfasst, das sich von öffnungen an beiden Enden des Durchflusskanals zu einem inneren Teil des Durchflusskanals hin verjüngt.

30. Energieerzeugungsvorrichtung nach Anspruch 2, wobei das Gehäuse im Wesentlichen symmetrisch um eine Mittelpunktsposition desselben ist und die/wenigstens eine der wenigsten einen Turbine(n) im Wesentlichen an derselben angeordnet ist.

31. Energieerzeugungsvorrichtung nach einem der Ansprüche 29 bis 30, wobei das Turbinengehäuse eine äußere Gehäusehülse und eine innere Gehäusehülse umfasst, wobei die innere Hülse den Durchflusskanal definiert.

32. Energieerzeugungsvorrichtung nach einem der Ansprüche 29 bis 31, wobei die Turbineneinheit einen Teil bereitstellt, der lösbar in der Turbineneinheit angebracht ist.

33. Energieerzeugungsvorrichtung nach einem der Ansprüche 1 bis 32, wobei die Turbineneinheit bei Anwendung als Reaktion auf einen Fluid-durchfluss in beiden Richtungen durch den Durchflusskanal angetrieben wird.

34. Energieerzeugungsvorrichtung nach Anspruch 2 oder einem der Ansprüche 3 bis 33, soweit abhängig von Anspruch 2, wobei ein Einlass- und/oder ein Auslassdurchmesser des Durchflusskanals oder der Durchführung ausgewählt ist von innerhalb des Bereichs von 7 m bis 40 m oder 20 m beträgt.

35. Energieerzeugungsvorrichtung nach Anspruch 2 oder einem der Ansprüche 3 bis 34, soweit abhängig von Anspruch 2, wobei eine Länge des Durchflusskanals oder der Durchführung in dem Bereich von 7 m bis 50 m liegt.

36. Energieerzeugungsvorrichtung nach einem der vorhergehenden Ansprüche, wobei die Energieerzeugungsvorrichtung einen Elektroenergie-Erzeuger umfasst.

37. Energieerzeugungsvorrichtung nach Anspruch 36, wobei die Energieerzeugungsvorrichtung dafür eingerichtet ist, Elektroenergie als Wechselstrom/-spannung (WS) oder Gleichstrom/-spannung (GS) zu erzeugen.

38. Verfahren zum Erzeugen von Energie, das die folgenden Schritte umfasst:

das Bereitstellen einer Energieerzeugungsvorrichtung (60) nach einem der Ansprüche 1 bis 37,
das Anordnen der wenigstens einen Turbineneinheit (30) der Energieerzeugungsvorrichtung unter Wasser,
das Veranlassen, dass sich die wenigstens eine Turbine (25) der wenigstens einen Turbineneinheit als Reaktion auf einen Fluiddurchfluss in wenigstens einer Richtung dreht.

39. Verfahren zum Erzeugen von Energie nach Anspruch 38, wobei die wenigstens eine Turbineneinheit auf, nahe oder über einem der folgenden angeordnet ist: einem Meeresgrund, einem Ozeanboden oder einer Fluss-Sohle.

40. Verfahren zum Erzeugen von Energie nach Anspruch 38 oder 39, wobei der Fluiddurchfluss einen Gezeitendurchfluss oder einen Strömungsdurchfluss umfasst.

41. Verfahren zum Erzeugen von Energie nach einem der Ansprüche 38 bis 40, wobei als Reaktion auf einen Fluiddurchfluss in einer Richtung sich die wenigstens eine Turbine in einer Richtung dreht und als Reaktion auf einen Fluiddurchfluss sich die wenigstens eine Turbine in einer anderen Richtung in einer anderen oder entgegengesetzten Richtung dreht.

42. Verfahren zum Erzeugen von Energie nach Anspruch 38, wobei das Gehäuse durch eine Anbringungsstruktur an einer Unterwasserfläche befestigt ist und wahlweise im Wesentlichen mit einer Richtung eines Gezeiten- oder Strömungsdurchflusses ausgerichtet ist.

43. Verfahren zum Erzeugen von Energie nach Anspruch 42, wobei ein Winkel zwischen einer axialen Richtung des Gehäuses und einer Richtung eines Gezeiten- oder Strömungsdurchflusses 0° bis 45° beträgt.

44. Verfahren zum Erzeugen von Energie nach Anspruch 42, wobei ein Winkel zwischen einer axialen Richtung des Gehäuses und einer Richtung eines Gezeiten- oder Strömungsdurchflusses 0° beträgt.

Revendications

1. Dispositif de production d'énergie (60), comprenant au moins une unité de turbine sous-marine (30), la au moins une unité de turbine sous-marine comprenant au moins une turbine (25), la au moins une turbine comprenant au moins une aube (20a-20e), **caractérisé en ce que** la au moins une aube comprend une pluralité de pales (5a-5e) espacées le long d'une longueur de la au moins une aube et entre un moyeu et une pointe de la au moins une aube, chaque pale ayant une forme symétrique à une ligne de corde médiane (A) de celle-ci et symétrique à une ligne de corde (B) de celle-ci, chaque pale comprenant des premier et deuxième bords d'attaque (10, 15), les premier et deuxième bords d'attaque des pales adjacentes étant reliés de sorte à établir des premier et deuxième bords d'attaque continus de la au moins une aube, un angle d'ajustement du moyeu de la au moins une aube étant compris dans l'intervalle allant de 30° à 60° à partir d'une direction axiale, et un angle d'ajustement de la pointe de la au moins une aube étant compris dans l'intervalle allant de 70° à 85° à partir d'une direction axiale.

2. Dispositif de production d'énergie selon la revendication 1, dans lequel la au moins une turbine englobe un carter (35), comportant un canal d'écoulement de fluide (40) le traversant, la au moins une turbine étant montée dans le canal d'écoulement en vue d'une rotation en réponse à l'écoulement du fluide à travers le canal d'écoulement.

3. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel chaque bord d'attaque a une forme en partie circulaire.

4. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel, pour chaque pale, un rapport entre la hauteur ou l'épaisseur de la ligne de corde médiane et la longueur de la ligne de corde est compris entre 5% et 25%.

5. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel, pour chaque pale, un rapport entre la hauteur ou l'épaisseur de la ligne de corde médiane et la longueur de la ligne de corde est compris entre 12% et 20%.

6. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel, pour chaque pale, un rapport entre la hauteur ou l'épaisseur de la ligne de corde médiane et la longueur de la ligne de corde correspond à 15%.

7. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel la forme de chaque pale comprend une forme du bord d'attaque NACA 67 réfléchie autour de la ligne de corde médiane.

8. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel la forme de chaque pale comprend une forme de bord d'attaque NACA 67_1-015 réfléchie autour de la ligne de corde médiane.

9. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel la au moins une aube comprend 3 à 9 pales.

10. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel la au moins une pale comprend cinq pales.

11. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel un rapport d'effilement de la au moins une aube est compris dans l'intervalle allant de 0,3 à 0,8.

12. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel le rapport d'effilement correspond à 0,5.

13. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel un rapport d'aspect de la au moins une aube est compris dans l'intervalle allant de 3 à 10.

14. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel un rapport d'aspect de la au moins une aube correspond à environ 6.

15. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel un angle d'ajustement du moyeu de la au moins une aube est compris entre 45° et 48°.

16. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel un angle d'ajustement de la pointe de la au moins une aube correspond à 79°.

17. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel une longueur de corde de la au moins une aube, au niveau de la mi-hauteur, est comprise dans l'intervalle allant de 0,3 à 3,0 m.

18. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel une longueur de corde de la au moins une aube correspond à 1,0 m.

19. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel la au moins une aube comprend une pluralité d'aubes.

20. Dispositif de production d'énergie selon la revendication 19, dans lequel la pluralité d'aubes comprend 2 à 9 aubes.

21. Dispositif de production d'énergie selon les revendications 19 ou 20, dans lequel la pluralité d'aubes comprend 3 à 7 aubes.

22. Dispositif de production d'énergie selon l'une quelconque des revendications 19 à 21, dans lequel la pluralité d'aubes comprend 5 à 7 aubes.

23. Dispositif de production d'énergie selon l'une quelconque des revendications 19 à 22, dans lequel un rapport entre le diamètre du moyeu et le diamètre de la pointe de la au moins une aube est compris dans l'intervalle allant de 0,1 à 0,5.

24. Dispositif de production d'énergie selon l'une quelconque des revendications 19 à 23, dans lequel un rapport entre le diamètre du moyeu et le diamètre de la pointe de la au moins une pale correspond à 0,2.

25. Dispositif de production d'énergie selon l'une quelconque des revendications 19 à 24, dans lequel un diamètre de la pointe est compris dans l'intervalle allant de 5 m à 30 m.

26. Dispositif de production d'énergie selon l'une quelconque des revendications 19 à à 25, dans lequel un diamètre de la pointe est compris entre 15 m et 20 m.

27. Dispositif de production d'énergie selon l'une quelconque des revendications 19 à 26, dans lequel la turbine est adaptée pour tourner, en service, à une vitesse compris entre 10 et 50 tours par minute.

28. Dispositif de production d'énergie selon l'une quelconque des revendications 19 à 27, dans lequel la turbine est adaptée pour tourner, en service, à une vitesse de 25 tours par minute.

29. Dispositif de production d'énergie selon la revendi-

cation 2, ou selon l'une quelconque des revendications 3 à 28, dépendant de la revendication 2, dans lequel le canal d'écoulement comprend un venturi comprenant un venturi convergent-divergent, effilé à partir d'ouvertures au niveau de chaque extrémité du canal d'écoulement vers une partie interne du canal d'écoulement.

30. Dispositif de production d'énergie selon la revendication 2, dans lequel le carter est pratiquement symétrique autour d'un emplacement médian de celui-ci, la/au moins une turbine de la (des) au moins une turbine(s) étant agencée pratiquement au niveau de cet emplacement.

31. Dispositif de production d'énergie selon les revendications 29 à 30, dans lequel le carter de la turbine comprend un manchon de carter externe et un manchon de carter interne, le manchon interne définissant le canal d'écoulement.

32. Dispositif de production d'énergie selon l'une quelconque des revendications 29 à 31, dans lequel l'unité de turbine comporte une partie pouvant être montée de manière amovible dans l'unité de turbine.

33. Dispositif de production d'énergie selon l'une quelconque des revendications 1 à 32, dans lequel l'unité de turbine est entraînée, en service, en réponse à l'écoulement de fluide dans chaque direction à travers le canal d'écoulement.

34. Dispositif de production d'énergie selon la revendication 2 ou selon l'une quelconque des revendications 3 à 33, dépendant de la revendication 2, dans lequel un diamètre d'entrée et/ou de sortie du canal d'écoulement ou du conduit est sélectionné dans l'intervalle allant de 7 m à 40 m, ou correspond à 20 m.

35. Dispositif de production d'énergie selon la revendication 2, ou selon l'une quelconque des revendications 3 à 34, dépendant de la revendication 2, dans lequel une longueur du canal d'écoulement ou du conduit est comprise dans l'intervalle allant de 7 m à 50m

36. Dispositif de production d'énergie selon l'une quelconque des revendications précédentes, dans lequel le dispositif de production d'énergie comprend un générateur d'énergie électrique.

37. Dispositif de production d'énergie selon la revendication 36, dans lequel le dispositif de production d'énergie est adapté pour produire de l'énergie électrique sous forme de courant alternatif/tension alternative (AC) ou de courant continu/tension continue (DC).

38. Procédé de production d'énergie, comprenant les étapes ci-dessous :

fourniture d'un dispositif de production d'énergie (60) selon l'une quelconque des revendications 1 à 17 ;
positionnement de la au moins une unité de turbine (30) du dispositif de production d'énergie sous l'eau ;
entraînement d'une rotation de la au moins une turbine (25) de la au moins une unité de turbine en réponse à l'écoulement de fluide dans au moins une direction.

39. Procédé de production d'énergie selon la revendication 38, dans lequel la au moins une unité de turbine est agencée, sur, près de, ou au-dessus d'au moins un des emplacements suivants : un fond marin, un plancher océanique ou un lit fluvial.

40. Procédé de production d'énergie selon lune des revendications 38 ou 39, dans lequel l'écoulement de fluide comprend un écoulement de marée ou un écoulement de courant.

41. Procédé de production d'énergie selon lune quelconque des revendications 38 à 40, dans lequel la au moins une turbine tourne dans une direction en réponse à l'écoulement de fluide dans une direction, la au moins une turbine tournant dans une autre direction ou dans une direction opposée en réponse à l'écoulement de fluide dans une autre direction.

42. Dispositif de production d'énergie selon la revendication 38, dans lequel le carter est fixé sur une surface sous-marine par une structure de montage et peut optionnellement être pratiquement aligné avec une direction de l'écoulement de marée ou de courant.

43. Dispositif de production d'énergie selon la revendication 42, dans lequel un angle entre une direction axiale du carter et une direction de l'écoulement de marée ou de courant est compris entre 0° et 45°.

44. Dispositif de production d'énergie selon la revendication 42, dans lequel un angle entre une direction axiale du carter et une direction de l'écoulement de marée ou de courant correspond à 0°.

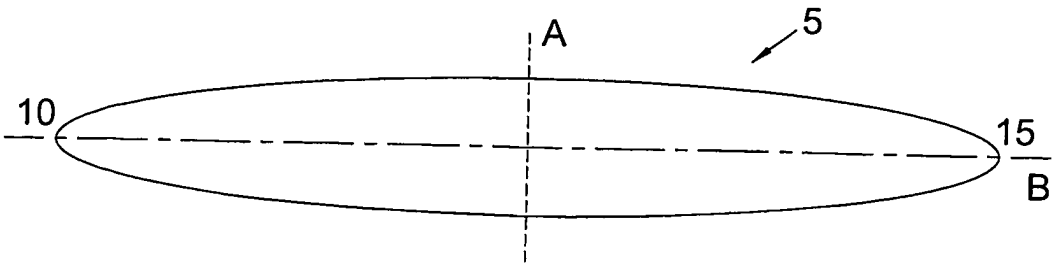


Fig. 1

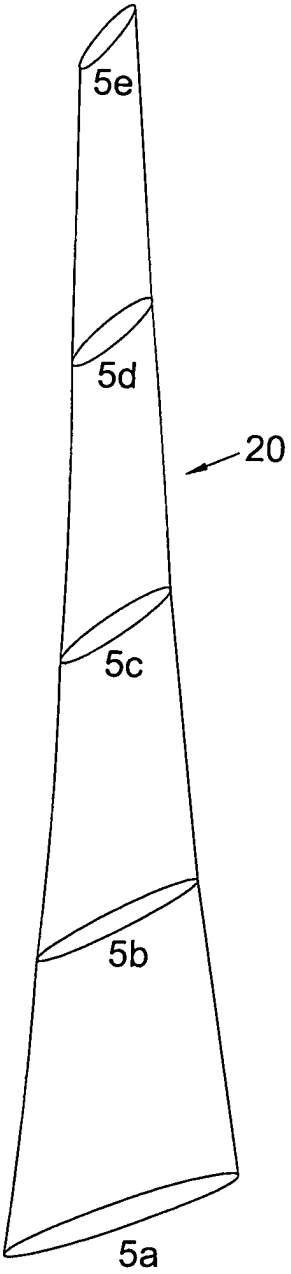


Fig. 2

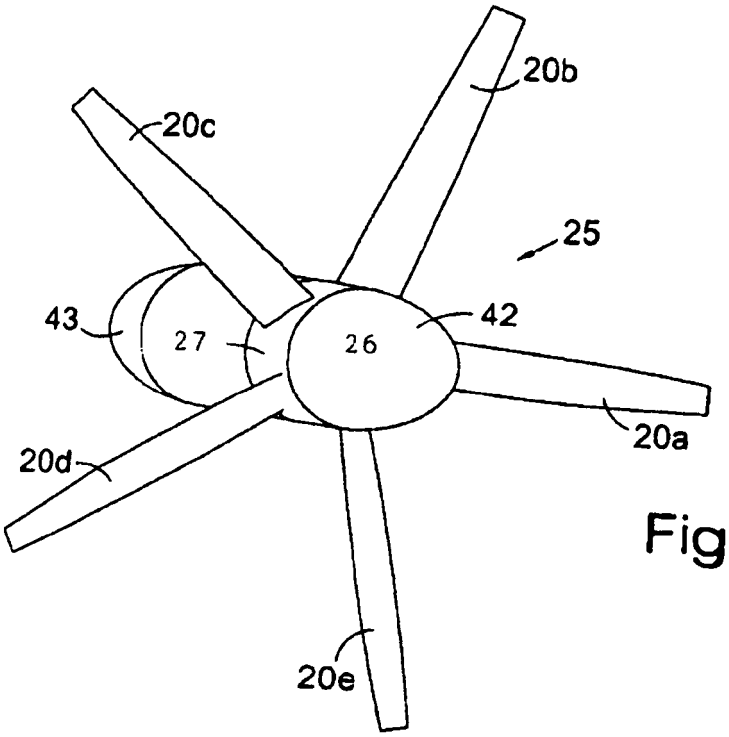


Fig. 3

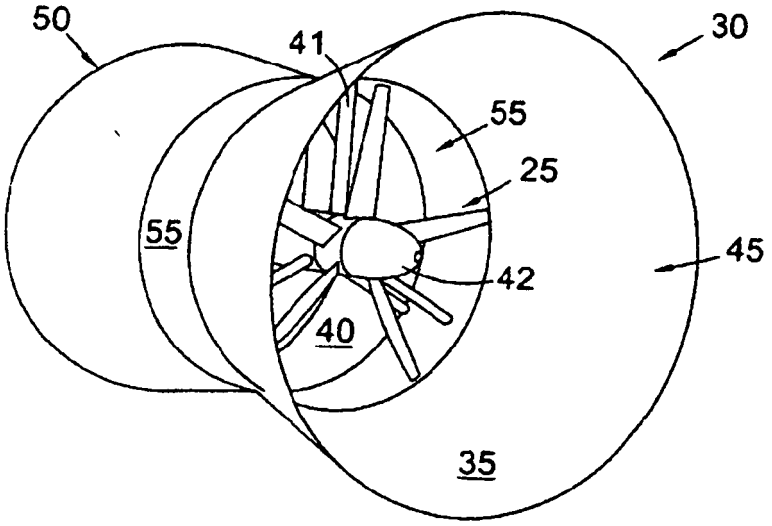


Fig. 4

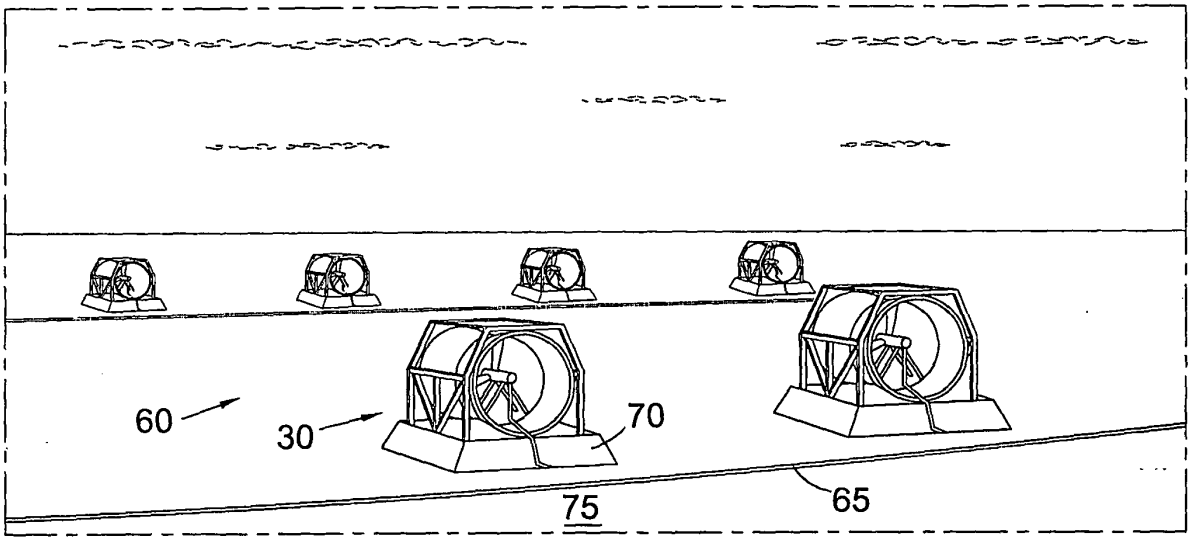


Fig. 5

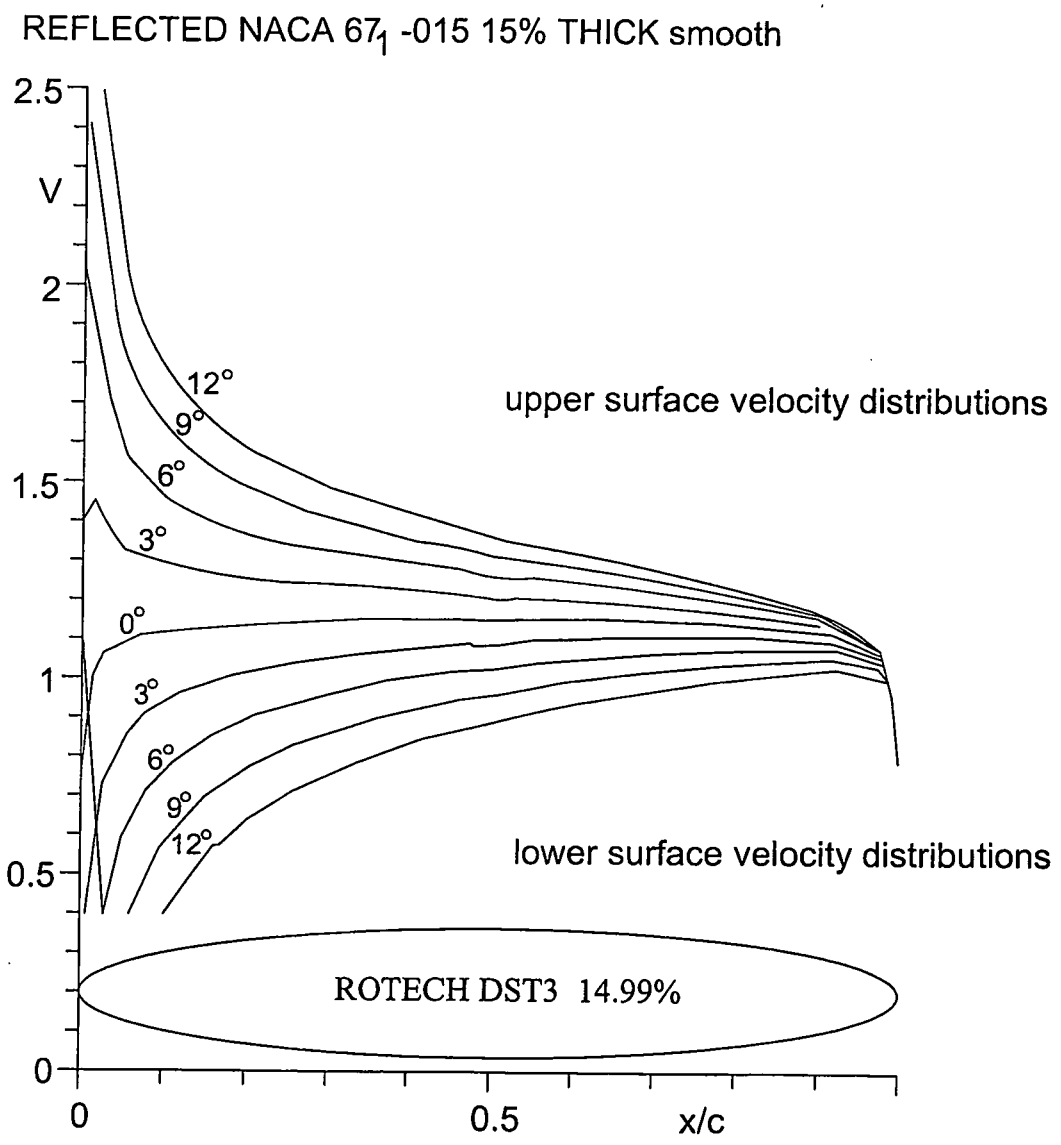

REFLECTED NACA 67$_1$ -015 15% THICK smooth
2.5
V
2
1.5
1
0.5
0
12°
9°
6°
3°
0°
3°
6°
9°
12°
upper surface velocity distributions
lower surface velocity distributions
ROTECH DST3 14.99%
0
0.5
x/c

Fig. 6

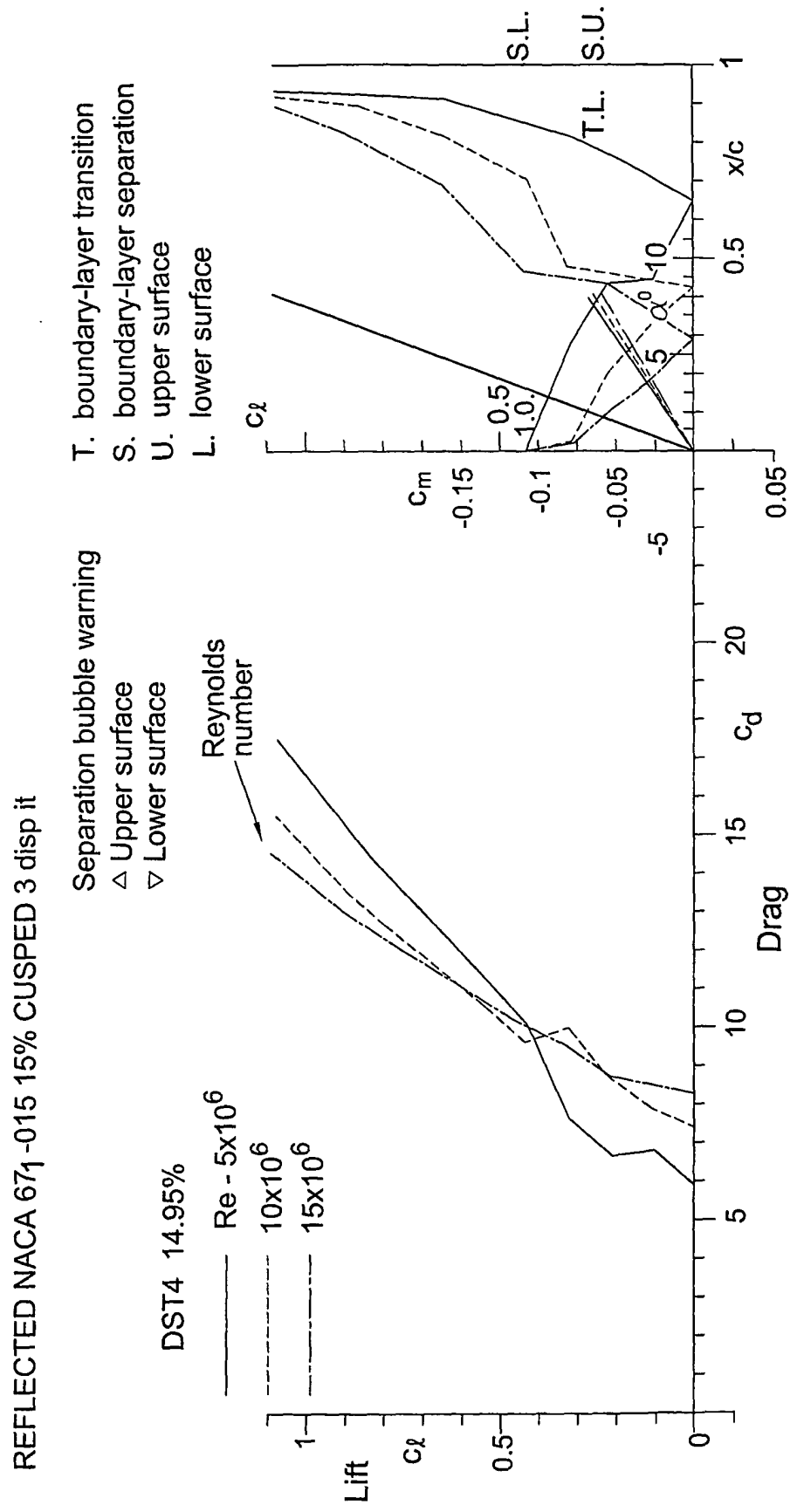

REFLECTED NACA 671-015 15% CUSPED 3 disp it
DST4 14.95%
Re - 5x10^6
10x10^6
15x10^6
Reynolds number
Separation bubble warning
△ Upper surface
▽ Lower surface
T. boundary-layer transition
S. boundary-layer separation
U. upper surface
L. lower surface
Lift
Drag
S.L.
S.U.
T.L.
x/c
α°

Fig. 7

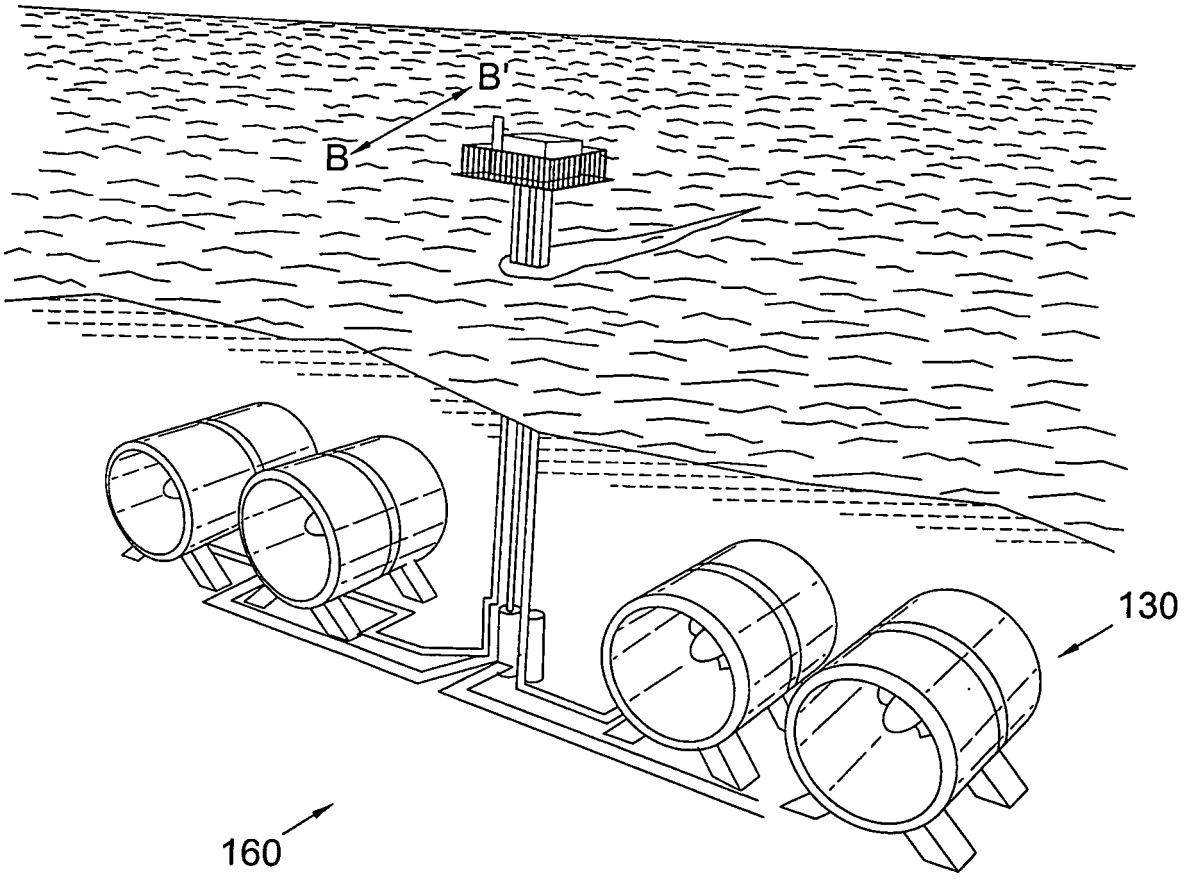


Fig. 8

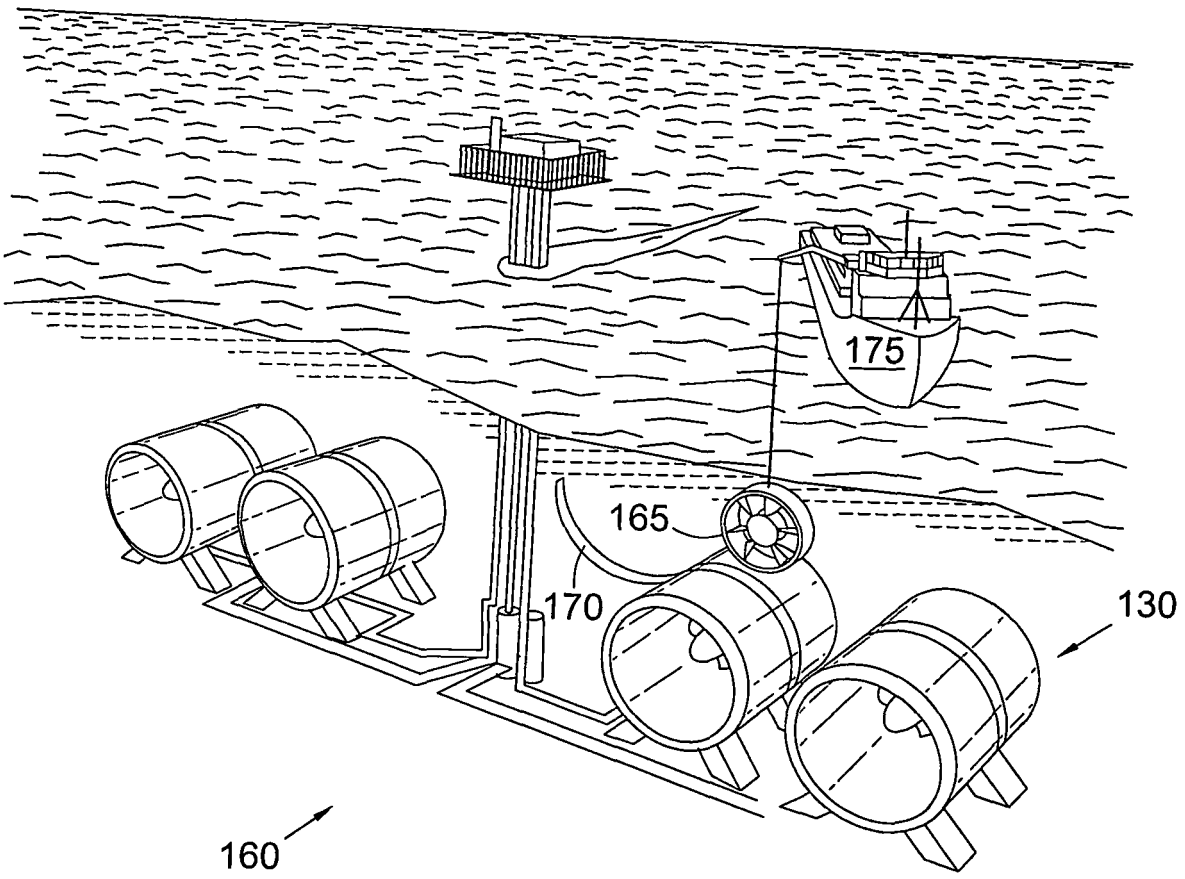


Fig. 9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 03029645 A **[0002]**
- WO 03029645 A1 **[0004] [0086]**
- CH 316900 A **[0005]**